LEBANON BOLOGNA

3832

I. MANUFACTURE AND PROCESSING

S. A. PALUMBO, J. L. SMITH, AND S. A. ACKERMAN
Eastern Regional Research Center[1]
Philadelphia, Pennsylvania 19118

ABSTRACT

A process devised in our pilot plant to manufacture Lebanon bologna consists of three steps: *(a)* aging salted beef at 5 C for 10 days; *(b)* smoking the stuffed bolognas at 35 C and high relative humidity for 4 days; and *(c)* mellowing the smoked bolognas at 5 C for 3 days. Aging the salted beef serves to enrich for a lactic microflora which will carry out the fermentation and for a micrococcal flora which will reduce nitrate to nitrite. Development of a firm cohesive structure which is characteristic of Lebanon bologna is related principally to acid production and only slightly to smoking. Fermentation occurs during the smoking period with the pH of the bolognas falling at least one pH unit during the first 2 to 3 days. Nitrate reduction and subsequent formation of nitrosylmyoglobin occur within the first 24 h. Flavor of Lebanon bologna is described as both acid and smoky. Both components develop during the lengthy incubation in the smoke house.

Lebanon bologna is a highly smoked, spiced, and fermented all-beef sausage originally made in the Pennsylvania Dutch area around Lebanon, Pa. Its manufacture probably represents an attempt to produce a sausage product similar to those of European origin. A sweet product, called sweet Lebanon bologna, is also produced. It is prepared in the usual fashion except that a larger quantity of sucrose (at least 10% instead of the usual 2%) is added along with the other ingredients just before the fermentation. Generally, the sweetness is great enough to mask the acid tang.

The traditional Lebanon bologna process may be summarized as follows: *(a)* beef is coarse chopped and salted (ca. 3%); *(b)* aged in wooden barrels in the cold (ca. 10 days at 5 C); *(c)* added KNO_3, sugar, and spices; fine grind; stuff into casings; *(d)* given a lengthy smoke at relatively low temperature and high relative humidity in wooden smoke houses (smoked at least 4 days at 35 C and 90+% relative humidity); and *(e)* mellowed after smoking (held ca. 3 days at 5 C).

The process of Lebanon bologna manufacture appears to be similar to that of other fermented, semidry sausages *(5, 11)* though little is known about it. There are relatively few published processes for Lebanon bologna *(2, 9, 10, 13)*, but, Federal specifications do exist for Lebanon-style bologna *(6)*. Despite the apparent scarcity of knowledge of the microbiology and technology of Lebanon bologna, considerable quantities are made in the Pennsylvania Dutch area. One processor produces over 100,000 lb/week *(2)*. Some manufacturers of Lebanon bologna claim that the sausage can not be made outside of the Lebanon area. Our purpose was to investigate the individual steps in Lebanon bologna manufacture and to define the technology of the process.

[1]Agricultural Research Service, U. S. Department of Agriculture.

MATERIALS AND METHODS

Meat

Freshly boned, whole, canner and cutter grade cow chuck was used throughout, except for one study in which cow knuckle was used. The meat was not trimmed before use.

Analyses

The moisture, fat, ash, and protein of the various sausages were determined by standard AOAC procedures *(3)*. Samples of the different bolognas or other sausages were ground twice through a 3/16-inch plate and analyzed. Samples of the ground sausages were also used for water activity (a_w) measurements using an Electric Hygrometer-Indicator (Model 15-3001, with gray sensor) (Hygrodynamics, Inc., Silver Spring, Md.[2]). The pH was measured with a Radiometer Corporation pH meter (model 25) equipped with a single combination electrode. The electrode was inserted directly into the sausage or into the mass of coarse ground (3/4 inch) beef cubes. The acid content of the sausages was determined as follows: a 10-g sample of the fine ground (3/16 inch) sample was freeze-dried; the freeze-dried material was extracted 6 to 7 h with ethyl ether in a Soxhlet apparatus. The ether extract was then titrated with standard base to the phenol red end point and the percent acid calculated by assuming that all acid was lactic. Cured meat color was determined by the aqueous acetone extraction method of Hornsey *(8)*.

[2]Reference to brand or firm name does not constitute endorsement by the U. S. Department of Agriculture over others of a similar nature not mentioned.

Casings

Either fibrous or cellulose casings (Union Carbide) were used. They were presoaked at 130 F before use.

Starter culture

For most studies, fermentation was accomplished with the natural flora of the meat encouraged by aging the meat with salt. For certain studies, Merck's Lactacel MC starter culture was used for acid production.

Texture

Texture (firmness) of Lebanon bologna was measured in two ways: *(a)* with a Warner Bratzler-type shear device (J. Chatillon and Sons, N. Y.), and *(b)* with a subjective description of the fermented bolognas. For the Warner Bratzler shear values, measurements were made on core samples

formed by a #13 cork borer (I. D., 20 mm) and were cut parallel to the long axis of the bolognas. Warner Bratzler shear measurements were made in an attempt to assign a numerical value to firmness of the bolognas. However, because of the non-homogenous nature of the bologna cores (it contained pieces of tough connective tissue along with the fine ground muscle), Warner Bratzler shear values did not agree completely with our subjective evaluation of texture, i.e., bolognas with similar numerical Warner Bratzler shear values were given different subjective descriptions of texture. In general, with most of the Warner Bratzler values, there was agreement between them and the subjective descriptions. In some experiments (c.f., Table 4), there was a progression of Warner Bratzler shear values; these data suggested that the bolognas became firmer with longer incubation.

Salt, spice mixture, and curing agents

Except where indicated, all bolognas contained 3% added salt (NaCl). Either potassium nitrate (1.85 g/kg meat) or sodium nitrite (0.078 g/kg meat) was used as the curing agent. Sodium nitrite was used in only a few experiments when Lactacel MC was employed. The following sugar-spice mixture was formulated based on published spice mixtures (*9, 10, 13*) and sugars used in Lebanon bologna:

sugar or spice	g/kg meat
glucose	20.0
sucrose	20.0
black pepper	2.50
nutmeg	1.25
allspice	1.25
red pepper	0.62
cloves	0.62
cinnamon	0.62
ginger	0.62
mustard	0.62
mace	0.02

The sugars and spices were premixed in a large quantity and weighed out as a single addition when the bolognas were prepared.

General procedure

The general procedure for Lebanon bologna preparation was as follows: Beef chuck was coarse ground through a 3/4-inch plate, 3% salt added and mixed with the meat; salted meat was then aged for 10 days at 5 C; after aging, the spice mixture and KNO_3 were added to the aged meat and mixed; this mixture was then fine ground through a 3/32-inch plate, stuffed into casings, and incubated in either *(a)* a Mepaco smoke house for 4 days at 35 C and 93% relative humidity (wet oak sawdust was used to generate the smoke); or *(b)* a constant temperature-constant humidity cabinet for 3 days at 35 C and 80% relative humidity. Eighty percent relative humidity was used to discourage mold growth on bolognas incubated in the cabinet; however, in the smoke house even at 93% RH, no mold growth occurred. After smoking, the bolognas were mellowed for three days at 5 C to allow desirable flavor changes to occur.

In the traditional Lebanon bologna process, meat is aged in a wooden barrel. We aged salted meat in a wooden barrel or in plastic bags and both methods were equally successful.

The bolognas were stuffed with either an E-Z Pak hydraulic stuffer (Minneapolis, Minn.) or a small laboratory hand stuffer. Using a small laboratory grinder and the hand stuffer, we were able to prepare bolognas with characteristics similar to those prepared with large-scale equipment from as little as 1 kg of meat.

Results

To determine the composition of Lebanon bologna as well as other fermented sausages, several commercial samples were obtained and analyzed. These data and those from our Lebanon bolognas are in Table 1. Our sweet Lebanon bologna, though it contained 10% sucrose, was not as sweet (judged by tasting) as commercial sweet Lebanon bologna. Percentages of acid in our sweet Lebanon bologna were at least double those in the commercial bolognas, indicating that high levels of sugar might have limited the fermentation in the commercial products.

The procedure for Lebanon bologna manufacture was derived empirically based on the few published formulae *(2, 9, 10, 13)*. The process appeared to be a lactic fermentation along with reduction of the nitrate to nitrite to yield cured meat color. In addition to its low pH, Lebanon bologna also has a characteristic firmness and cohesive texture. It was therefore decided to investigate the effect of the three main steps of Lebanon bologna manufacture, aging, smoking, and mellowing on flavor, as well as the factors responsible for texture of Lebanon bologna.

Texture study

Inside portions of cow knuckle were handled in such a fashion as to minimize contamination and keep the bacteriological count low. These inside portions were then coarse ground through a sterile grinder and held in sterile trays. The coarse ground meat was then divided into 1-kg batches and aged at 5 C, 4 batches with and 8 batches without salt. When this aged meat was made into bolognas, salt was added to half of the non-salted batches. Bolognas were made from meat aged 0, 5, and 10 days, with and without the addition of Lactacel MC starter culture and/or the gram-negative rod culture isolated from unsalted aged beef cubes (see Table 2). After incubation in the cabinet, the bolognas were evaluated bacteriologically (Smith and Palumbo, in preparation) and for texture (firmness) and pH. The data from bolognas made from meat aged 10 days are in Table 2. Similar data were obtained from bolognas made from meat aged 5 days. Of bolognas prepared without aging, the only bologna that was firm and had the typical structure was the one made with both salt and starter culture.

Salt added to meat before aging inhibits the gram-negative rod microflora (Smith and Palumbo, in preparation). When gram-negative rods were absent, the characteristic texture of Lebanon bologna was obtained by adding salt to the aged meat before preparation of the bolognas.

Salt concentrations

Table 1. Compositional analyses and chemical measurements of Lebanon bologna and other sausages

Sausage/Company/Description	Moisture (%)	Ash (%)	Fat (%)	Protein (%)	a_w	pH	Percent acid as lactic
Regular Lebanon bologna							
Our product – Expt. #3	61.13	3.96	10.76	20.19	0.963	4.50	1.27
Our product – Expt. #2	62.53	5.04	12.15	–	–	4.50	–
Our product – made with Lactacel MC	–	–	–	–	0.963	4.60	1.31
Company A	59.60	4.90	13.30	–	0.958	4.60	0.86
Company B	50.95	4.52	22.34	–	0.977	4.60	0.86
Company C	47.39	4.91	22.25	–	0.934	4.70	0.77
Company D	49.80	5.0	24.4	17.6	0.98	4.80	0.46
Company F	59.75	4.67	12.15	22.38	0.965	4.60	1.22
Company G	57.50	5.14	16.09	19.46	0.955	4.90	0.77
Sweet Lebanon bologna							
Our product	58.65	3.69	7.70	18.37	0.960	4.40	1.12
Company A	51.90	5.90	11.90	–	0.982	4.90	0.34
Company B	49.14	3.98	13.64	–	0.98	4.80	0.39
Company D	47.82	4.76	17.39	16.31	0.937	4.90	0.33
Company G	54.77	4.38	16.20	17.18	0.965	4.90	0.65
Sweet bologna (non-emulsion, non-fermented)							
Company C	57.01	4.62	16.13	–	0.99	5.6	0.19
Lebanon bologna (non-smoked)							
Our product	53.34	4.74	13.67	24.80	0.95	4.60	1.09
Italian salami	24.25	7.14	39.77	20.32	0.793	5.20	0.47
Cervelat	29.40	4.60	44.4	–	0.930	4.80	0.40
Thuringer	36.58	5.05	37.15	17.28	0.923	4.95	0.70

Table 2. Effect of salt and starter culture on texture development (firmness) in Lebanon bologna[1]

Addition of 3% salt		Addition of culture			Firmness	
Before aging	Before bologna preparation	Gr – rod	Lactacel MC	pH	Warner-Bratzler shear value, lb.	Description
+	–	+	+	4.60	3.3	Firm
+	–	+	–	5.25	2.2	Soft
–	–	–	+	4.50	4.5	Very firm
–	–	–	–	5.30	0.8	Very soft
–	–	+	+	4.75	1.9	Soft & grainy
–	–	+	–	4.60	1.6	Soft & grainy
–	–	–	+	4.75	1.4	Soft & grainy
–	–	–	–	4.70	2.0	Soft & grainy
–	+	+	+	4.60	3.8	Very firm
–	+	+	–	4.70	2.3	Soft & grainy
–	+	–	+	4.60	3.9	Very firm
–	+	–	–	5.20	0.3	Soft

[1]Meat aged 10 days at 5 C.

Meat was aged for 10 days with salt concentrations varying from 0 to 4%. At the time of preparation of bolognas, additional salt was added to portions of aged meat having < 3% salt to bring the final salt content to 3% total added salt. The stuffed bolognas were incubated in the cabinet for 3 days and evaluated for pH, color, and texture. These data are in Table 3.

Amount of drip and odor of the meat during aging appeared to be related to the concentration of salt. Meat aged with 2 to 4% salt did not drip at any time during the 10-day aging period or develop off-odor. In contrast, meat aged with none or 1% salt showed considerable drip and had pronounced off odor that seemed to be related to the development of the gram-negative rod microflora (Smith and Palumbo, in preparation).

Four percent salt present during the aging process appeared to interfere with development of the desired lactic microflora since the pH did not drop (Table 3). However, meat aged with 3% salt that had an additional 1% added during processing yielded bolognas similar in texture, color, and pH to those made from meat aged with 3% salt.

Smoke study

To determine the exact sequence of changes occurring in the meat during normal Lebanon bologna manufacture, salted meat and the resulting bolognas were evaluated sequentially using the criteria of pH, color, and firmness. During the 10-day aging period, the pH of the salted meat remained at the starting pH of 5.6. During incubation in the smoke house or the cabinet, the pH fell (Table 4). The meat was completely cured within the first 24 h and no further cured meat color developed during the last 3 days of incubation. During incubation, the bolognas became firmer (Table 4); smoked bolognas appeared to be firmer than non-smoked ones. Based on the aforementioned studies, firmness and texture of Lebanon bologna were shown to be dependent principally on acid production, whether by the natural flora or added starter culture, and only to a limited degree on smoking. Salt is also necessary for firmness and good texture. One commercial firm smokes their Lebanon bologna until it firms up and has the proper color and texture.

Casings

Among the three casings tested for Lebanon bologna, the cellulose casing allowed less than half as much moisture loss as the fibrous casing (Table 5). Bolognas in cellulose casing, however, had to be hung in stockinettes during smoking; bolognas in fibrous casings were hung without additional support.

Length of aging

Meat for preparation of Lebanon bologna normally is aged for 10 days. In one study, salted meat was made into bolognas after different aging times, and after incubation in the cabinet, bolognas were evaluated for texture and pH. In this particular study, it took 14 days instead of the usual 10 to give the desired pH drop and subsequent texture development (Table 6). The additional aging time required for this batch of meat to reach the proper acidity was due to the slow development of lactic acid-producing bacteria (Smith and Palumbo, in preparation).

In a separate experiment, fresh meat was salted and made into Lebanon bologna without aging. These bolognas were evaluated daily for pH and texture. During 12 days' incubation in the cabinet, the pH did not change and firm texture did not develop; cured meat color was observed after 2 days' incubation. A separate portion of this fresh meat was salted, aged at 5 C for 12 days, and then made into bolognas. The pH of these bolognas fell to 4.7 after 3 days' incubation in the cabinet. The microbiology of this experiment is considered elsewhere (Smith and Palumbo, in preparation), but the lack of fermentation in the bolognas made from fresh meat appeared to be related to the starting concentration of lactic acid bacteria in the meat. The fermentation in the aged-meat bolognas demonstrated that the meat would support a fermentation if aged at 5 C to develop the desired bacterial flora.

TABLE 3. INFLUENCE OF DIFFERENT SALT CONCENTRATIONS DURING AGING ON PH, COLOR, AND FIRMNESS OF LEBANON BOLOGNA[1]

	Characteristics of finished bolognas			
			Firmness	
% Salt	pH	Hornsey cured meat color value	Warner-Bratzler shear value, lb.	Description
0	4.71	2.90	0	Soft
1	4.78	2.70	1.5	Soft
2	4.60	2.20	2.1	Firm
3	4.85	3.50	2.4	Firm
4	5.55	0.50	0	Soft
3 + 1[2]	4.60	3.0	3.0	Firm

[1]Meat aged 10 days at 5 C.
[2]Meat was aged with 3% salt; an additional 1% salt was added when the bologna was prepared.

TABLE 4. CHANGES IN PH, COLOR, AND FIRMNESS OCCURRING DURING SMOKING OR INCUBATION OF LEBANON BOLOGNA[1]

			Firmness	
Days	pH	Hornsey cured meat color value	Warner-Bratzler shear value, lb.	Description
Smoked				
1	5.05	1.7	2.9	Firm
2	4.40	1.7	4.6	Very firm
3	4.60	1.7	4.7	Very firm
4	4.60	1.7	4.4	Very firm
Incubated				
1	5.1	1.7	1.6	Slightly firm
2	4.50	1.7	2.1	Firm
3	4.80	1.7	3.0	Firm
4	4.75	1.7	2.9	Firm

[1]pH of meat before smoking or incubation was 5.6.

TABLE 5. EFFECT OF TYPE AND SIZE OF CASING ON SHRINK DURING FOUR DAYS OF SMOKING AT 35 C AND 93% RH

Code	Casing type	Diameter	Percent shrink (moisture loss)
1A	cellulose	85 mm	2.44
1B	fibrous	85 mm	6.26
1C	fibrous	55 mm	7.01

TABLE 6. INFLUENCE OF LENGTH OF AGING WITH 3% SALT ON PH AND TEXTURE OF LEBANON BOLOGNA

		Firmness	
Days of aging	pH	Warner-Bratzler shear value, lb.	Description
0	5.55	0	Soft
1	5.65	0	Soft
3	5.75	0	Soft
6	5.35	2.1	Firm
8	5.25	2.1	Firm
10	5.15	3.3	Very firm
14	4.50	3.3	Very firm

TABLE 7. INFLUENCE OF DIFFERENT FREEZING TREATMENTS ON PH, COLOR, AND FIRMNESS OF LEBANON BOLOGNA

		Bologna evaluation		
			Firmness	
Meat and treatment	pH	Color	Warner-Bratzler shear value, lb.	Description
Frozen, thawed, salted, and aged 10 days	4.55	+	4.8	Very firm
Salted and aged 10 days; frozen, thawed, and made into bolognas	4.55	+	4.9	Very firm
Salted and frozen with no aging; thawed and made directly into bolognas	5.8	+	0	Soft
Frozen with no salt or aging; thawed and salt added and made into bolognas directly	5.72	+	0	Soft
Frozen, thawed, and salted; no aging (lactacel MC added) (incubated only 24 hr in smokehouse)	4.60	+	4.5	Very firm
Fresh; salted; no aging	5.70	+	0	Soft

Fresh versus frozen meat

Throughout most of these studies fresh meat was used. However, under certain circumstances, it might be desirable to prepare Lebanon bologna from frozen beef. Data on bolognas prepared from beef frozen at different stages of Lebanon bologna manufacture are presented in Table 7. These data indicate the following: *(a)* frozen meat could be made into Lebanon bologna of good texture, color, and pH if the meat was aged with salt after thawing or if starter culture was added; and *(b)* meat could be frozen after aging, thawed, and made into Lebanon bologna (the bacterial flora remains viable during the freezing and thawing). All bolognas described in Table 7 showed the typical cured meat color of Lebanon bologna. Thus, freezing did not seem to interfere with the nitrate-reducing flora or with the meat's enzymatic systems for producing cured meat color.

Flavor

A trained taste panel evaluated Lebanon bologna produced in our laboratory. Various bolognas made by the above described process were judged by the panel using the triangle test. The panel was best able to distinguish differences when one of the samples was smoked. Smoke was important in picking out differences between samples and in preferences; smoked samples were preferred over non-smoked in almost all instances. Some samples had higher than usual pH values (4.9 versus 4.5) and in general, panelists could distinguish and preferred the more acid bolognas.

The mellowing process was also evaluated by the taste panel by employing a hedonic scale. Lebanon bolognas just removed from the smoke house and cooled were compared with Lebanon bolognas mellowed 3 days at 5 C. The panel rated the mellowed bolognas just slightly higher than those freshly removed from the smoke house. However, the difference was not statistically significant. Our own observation indicated that during mellowing, the flavor of the spices became less pronounced and the acid tang less sharp, but, the taste panel was unable to pick out these subtle differences. Most commercially fermented sausages are probably mellowed during the period between production and consumption and this period is generally at least the 3 days suggested for these products (9).

Several commercial Lebanon bolognas were compared to our own Lebanon bolognas using the triangle test. Based on flavor, the panel could distinguish ours from the commercial samples and preferred ours over the commercial samples in all instances. The commercial Lebanon bolognas used included representative samples of the major Lebanon bolognas produced and available in this area.

DISCUSSION

In the preparation of Lebanon bologna, the most critical step appears to be aging of salted beef. An optimum concentration of salt is needed to produce a bologna with good texture (Table 3). Too much salt appears to inhibit development of proper microflora as evidenced by limited pH drop and inadequate development of cured color. Too little salt permitted extensive development of gram-negative rods, producing bolognas with good color and pH, but soft,

grainy texture. The time salted meat is aged is also related to development of the necessary lactic microflora to produce the pH drop. In most experiments, a 10 day aging period was adequate.

Pederson and Albury *(12)* considered the influence of salt concentration in another naturally fermented food, sauerkraut. They found that salt concentration was the single most important factor which governed the course of the fermentation. Too high a salt concentration (3.5%) allowed formation of sauerkraut with lower acidity (as lactic acid) and lower pH; this sauerkraut was poor in color, flavor, and texture. Too low a concentration of salt (1%) yielded sauerkraut with soft texture, but good color. At 1% salt, the acidity (% acid as lactic) was not affected, but the pH did not fall as low as it did when 2.25 and 3.5% salt were added.

Salt is necessary for proper aging of chopped beef for bolognas since it discourages development of gram-negative spoilage bacteria. While inhibiting almost all bacteria, salt is especially valuable because it encourages growth of micrococci (Smith and Palumbo, in preparation). Salt is also necessary for development of texture (cohesive structure) of the Lebanon bologna. When not needed to suppress growth of gram-negative rods during aging, salt can be added at the time bolognas are prepared (Table 2).

Data in Table 3 suggest that the presence of high concentrations of salt (4%) during aging inhibited both cured meat color formation and production of acid during fermentation. The lack of acid production (high pH) was due to the inhibition of the growth of the lactic acid bacteria by the 4% salt (Smith and Palumbo, in preparation). However, the number of micrococci which reduce nitrate are stimulated by increasing concentrations of salt. Development of cured meat color also may be influenced by the high pH. Fox and Thomson *(7)* observed that formation of nitrosylmyoglobin was very pH-dependent; the reaction was 20 to 30 times as fast at pH 4.5 as at pH 5.5. Since the pH of the bolognas made from meat aged with 4% salt remained high, formation of nitrosylmyoglobin apparently was inhibited. Analyses of the nitrate and nitrite content of the different bolognas might have clarified this point. Despite the presence of a micrococcal flora capable of reducing nitrate to nitrite and conditions not favorable for nitrosylmyoglobin formation, "nitrite burn" *(4)* was not observed.

Considerable variation in Hornsey color values was observed between the different experiments (Tables 3 and 4), and reflects differences in the amounts of nitrosylmyoglobin formed during the respective experiments. Since the amount of nitrosylmyoglobin is dependent upon factors such as pH and amount of nitrite (formed by bacterial reduction of nitrate) as well as other factors including the meat pigment itself, variation can be expected. There is good agreement within the respective experiments.

The compositional and chemical analyses (both of our own and of commercial samples of Lebanon bologna) represent the only data of this type that are available in the literature (Table 1). Examination of the compositional analysis data indicate that Lebanon bologna produced in our pilot plant was similar to the commercial product. Generally, our Lebanon bologna had less fat than the commercial ones. These compositional data for all sausages except the Italian salami, Cervelat, and Thuringer (Table 1) show that these sausages are high in protein and low in fat and would provide good nutrition in the diet. The last three sausages in Table 1 are considered to be of the dry type and their low moisture content reflects this. They are also characterized by a much higher fat content.

In general, the percent acid of Lebanon bolognas prepared in our laboratory was higher than that found in commercial Lebanon bolognas. Our Lebanon bologna was prepared under more carefully controlled conditions of salt concentration, and of time and temperature of aging. This rigid control may be reflected in better acid production. Furthermore, we used freshly boned chuck with no trimmings added. The meat was ground and salted either the same day or the next day after boning.

The a_w values observed for most of these sausages were relatively high and thus a_w probably did not form the sole basis for the long shelf life of Lebanon bologna (Table 1). One sample of commercial Lebanon bologna sliced in our laboratory showed no sign of visible spoilage after 12 months' storage at 20 C. This long shelf life was probably related to the extensive smoking of the bolognas along with their lactic acid content and low pH.

The shelf lives of several smoked and non-smoked Lebanon bolognas produced in our pilot plant were studied. The variables included smoked and non-smoked bolognas, with and without spices which were fermented with natural lactic flora or with Merck's Lactacel MC. The bolognas were taken to a local market where a small quantity of each was sliced; these slices were wrapped in Saran, stored at 20 C, and observed daily. The slices from the various non-smoked bolognas showed mold growth within 1 week. Those from the various smoked bolognas showed no mold after 4 weeks. This observation further supports the above statement that the extensive smoking contributes a major portion to the shelf life of Lebanon bologna.

Throughout these studies, we employed an aging temperature of 5 C, except for one study in which we used 11 and 16 C. These two elevated temperatures appeared satisfactory for development of the necessary microflora, as evidenced by the pH drop and color of the bolognas. However, 5 C is the recommended aging temperature because growth of foodborne pathogens is inhibited at this temperature *(1)*.

The special wooden smoke houses used by most commercial firms to smoke Lebanon bologna allow them to achieve, without difficulty, the long low-temperature incubation required to produce this sausage product. We employed a modern air conditioned smoke house and had difficulty maintaining 93% relative humidity at 35 C. After modification of the smoke house to function at low temperature and high relative humidity, we were able to maintain these conditions for the regular 96-h smoke given our product.

Our Lebanon bologna did have one defect which we were unable to correct. The bolognas had a somewhat dry, dark outer layer just beneath the casing. The layer was about 1/2-inch thick and dark brown in color. The layer may represent a heavy accumulation of smoke along with some dehydration of this outer portion of the bologna. This dried layer was observed with both fibrous and cellulose casings with as little as one day of smoking. One explantion may be that the wooden smoke houses used to make this product commercially have no means of circulating the smoke, while in our smoke house, the smoke was continuously circulated and forced through the house. This continual circulation of slightly less than water-saturated smoke (93% relative humidity) may provide a drying effect and produce this dry, dark layer.

The acid production and nitrate reduction pattern observed during smoking of Lebanon bologna was similar to that reported for summer sausage by Deibel et al. *(5)*. Nitrate reduction and subsequent curing occurred very early in the smoking, while acid production was somewhat slower. Deibel et al. *(5)* also reported that soft texture of summer sausage was associated with high pH values in the sausage. This is essentially our observation with Lebanon bologna; firm, cohesive characteristic texture was produced only with a good fermentation (pH drop) and in the presence of salt.

In defining Lebanon bologna flavor, two criteria seem to describe it: smoke and acid tang. Bolognas possessing both these characteristics were preferred by the taste panel and judged "typical." Certain commercial Lebanon bolognas are only smoked for relatively short periods and in general these lack typical Lebanon bologna flavor. These same bolognas are prepared with starter cultures. We have found that with starter culture, too long an incubation (smoking) tends to yield undesirable flavors. Starter cultures allow a faster pH drop, and make the bolognas safer from a public health point of view, but they do not permit the long smoking necessary to give the typical Lebanon bologna flavor.

Acknowledgments

We thank Florence B. Talley for the taste panel evaluation of the Lebanon bolognas; we also thank Lawrence Cohn, Robert Sirovetz, and Michael Fulton for assistance during the processing operations.

References

1. Angelotti, R., M. J. Foter, and K. H. Lewis. 1961. Time-temperature effects on salmonellae and staphylococci in foods. I. Behavior in refrigerated foods. Amer. J. Pub. Health 51:76-88.
2. Anonymous. 1966. It's different. Natl. Provisioner 154(8):16-19.
3. A.O.A.C. 1965. Official methods of analysis. 10th ed. Association of Official Agricultural Chemists, Washington, D. C.
4. Deibel, R. H., and J. B. Evans 1957. "Nitrite burn" in cured meat products—particularly in fermented sausages. American Meat Institute Foundation, Bulletin No. 32.
5. Deibel, R. H., C. F. Niven, Jr., and G. D. Wilson. 1961. Microbiology of meat curing. III. Some microbiological and related technological aspects in the manufacture of fermented sausages. Appl. Microbiol. 9:156-161.
6. Federal Specification PP-B-575A. Oct. 20, 1971. Bologna, chilled or frozen: Lebanon style. U. S. Army Natick Labs., Natick, Mass.
7. Fox, J. B., Jr., and J. S. Thomson. 1963. Formation of bovine nitrosylmyoglobin. I. pH 4.5 - 6.5. Biochemistry 2: 465-470.
8. Hornsey, H. C. 1956. The colour of cooked cured pork. I. Estimation of the nitric oxide-Haem pigments. J. Sci. Food Agr. 7:534-540.
9. Merck Technical Service. 1959. ACCEL for the production of thuringer, summer sausage, cervelat. Lebanon bologna, and pork roll. No. AC-2002.
10. National Provisioner. 1938. Sausage and meat specialties. The Packers' Encyclopedia, part 3. National Provisioner, Chicago, Illinois.
11. Pederson, C. S. 1971. Microbiology of food fermentations. pp. 153-172. AVI Publishing Co., Westport, Conn.
12. Pederson, C. S., and M. N. Albury. 1954. The influence of salt and temperature on the microflora of sauerkraut fermentation. Food Technol. 8:1-5.
13. Zeigler, P. T. 1968. The meat we eat. 9th ed. Interstate, Danville, Illinois.